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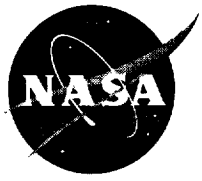

Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jeffrey A. Newcomer, Editors

Volume 11

BOREAS AFM-6 NOAA/ETL 35 GHz Cloud/Turbulence Radar GIF Images

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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

June 2000

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June 2000

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BOREAS AFM-6 NOAA/ETL 35-GHz Cloud/Turbulence Radar GIF Images

Brooks E. Martner

Summary

The BOREAS AFM-6 team from NOAA/ETL operated a 35-GHz cloud-sensing radar in the NSA near the OJP tower from 16-Jul-1994 to 08-Aug-1994. This data set contains a time series of GIF images that show the structure of the lower atmosphere.

Note that these data are not contained on the BOREAS CD-ROM set. See Sections 15 and 16 for information about how to acquire the data.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS AFM-06 NOAA/ETL 35-GHz Cloud/Turbulence Radar GIF Images

1.2 Data Set Introduction

This data set contains Graphical Interchange Format (GIF) images derived from radar data. The data were collected over the months of July and August in the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) approximately 1 km northeast of the Old Jack Pine (OJP) tower. The images provide a visual depiction of the atmospheric structure during the data collection periods. The radar reflectivity in dBZ units (which are commonly used in radar meteorology) is the intensity of the backscattered signal, and for water droplets it is related to the size and concentration of the drops. The hotter the color the stronger the returned signal.

1.3 Objective/Purpose

The field work objective was to measure turbulence characteristics of the outer boundary layer (above 100 m above ground level (AGL)) and the structure and kinematics of tropospheric clouds, including multiple cloud layer heights and thicknesses. The scientific analysis goal is to use these radar measurements, in combination with tower and aircraft flux measurements, to examine how clouds and outer boundary layer motions affect surface layer fluxes. The data may also be useful for extending the height-limited momentum flux measurements.

1.4 Summary of Parameters

Parameters measured by the radar at every range gate include:

- radar reflectivity factor (dBZ)
- radial Doppler velocity (m/s)
- variance of the Doppler velocity spectrum (m^2/s^2)
- depolarization ratio (dB)

Various other parameters, such as momentum fluxes, may be derived from these basic measurements.

1.5 Discussion

National Oceanic and Atmospheric Administration (NOAA) Environment Technology Laboratory (ETL) personnel operated a 35-GHz cloud-sensing radar in the BOREAS NSA throughout Intensive Field Campaign (IFC)-2 during midsummer of 1994. This work is one aspect of the research by the Airborne Fluxes and Meteorology (AFM)-06 team. The other aspect was the data collection by a 915-MHz wind profiler/Radio Acoustic Sounding System (RASS) in the Southern Study Area (SSA), as documented in a separate data set.

The .gif files are time-height images of the structure and kinematics of clouds and other particulate scatters (such as insects) over the radar site for periods when the radar was pointing at the zenith. Thus, the images provide a history of the clouds, etc., as they passed over the radar. Insect echoes are limited to the boundary layer, usually less than 2 km above ground. Stratus clouds sometimes also occupied those low altitudes.

1.6 Related Data Sets

BOREAS AFM-05 Level-1 Upper Air Network Data
BOREAS AFM-05 Level-2 Upper Air Network Standard Pressure Level Data
BOREAS AFM-06 Boundary Layer Height Data
BOREAS AFM-07 SRC Surface Meteorological Data
BOREAS TF-08 NSA-OJP Tower Flux, Meteorological, and Soil Temperature Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Robert Banta, Brooks Martner, James Wilczak NOAA Environmental Technology Laboratory

2.2 Title of Investigation

Outer Boundary Layer Effects on Surface Fluxes of Momentum, Heat, Moisture, and Greenhouse Gases from the Boreal Forest

2.3 Contact Information

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Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-7858
(301) 286-0239 (fax)
Jeffrey.Newcomer@gsfc.nasa.gov

3. Theory of Measurements

The radar is an active remote sensor that transmits pulses of microwave energy and receives signals backscattered from targets in the beam. The Doppler shift caused by the targets' motions is determined by measuring and comparing the phase of the transmitted and received signals. In the BOREAS data set, the targets are primarily cloud hydrometeors and/or insects. Both are treated as tracers of the atmospheric motions.

4. Equipment

4.1 Sensor/Instrument Description

The cloud-sensing radar is a 35-GHz (8-mm wavelength, Ka-band) Doppler, dual-polarization system developed at NOAA/ETL. Its Doppler capability allows the velocity of the backscattering targets to be measured, and its short wavelength (compared to storm-monitoring radars) gives it the ability to detect clouds as well as precipitation. It can also obtain measurements in the cloudless boundary layer from backscatter off of insects, bits of vegetation, seeds, and perhaps giant aerosols that are prevalent in warm seasons over continental locations.

Two scanning modes were used in BOREAS:

- Vertical. The antenna pointed continuously at the zenith. In this mode, high-resolution measurements were obtained of vertical velocity fluctuations in the boundary layer as a function of time and height. It also provided uninterrupted monitoring of cloud conditions over the site.
- Conical. The antenna repeated a series of four elevation sweeps (35, 51, 69, and 90 degrees above the horizon) every 6 minutes. This mode allowed the horizontal components of the wind to be measured in addition to the vertical wind. Postprocessing with velocity azimuth display (VAD) software computes profiles of the mean wind, momentum fluxes (u'w', v'w'), and higher order turbulence statistics for a large volume of air over the radar.

Two separate data time-height images of the vertically pointing data in .gif format. The other will contain tabular files of the profiles of wind, momentum flux, and other parameters in American Standard Code for Information Interchange (ASCII) format.

- NOAA/ETL 35-GHz Cloud/Turbulence Radar
- Range resolution = 37.5 m
- Range limits = 0.15 - 12.4
- Temporal resolution = 3.33 Hz (vertical mode)

(Complete hardware and operating characteristics table can be obtained from B. Martner, NOAA/ETL.)

4.1.1 Collection Environment

Data were collected during a variety of weather conditions, as described in Section 7.2.

4.1.2 Source/Platform

The radar was ground-based and mounted on two trailers.

4.1.3 Source/Platform Mission Objectives

The purpose of the trailers was to contain and support the radar measurement equipment.

4.1.4 Key Variables

Radar reflectivity factor (dBZ)
Radial Doppler velocity (m/s)
Variance of the Doppler velocity spectrum (m^2/s^2)
Circular Depolarizaton Ratio (dB)

4.1.5 Principles of Operation

Standard Doppler radar techniques.

4.1.6 Sensor/Instrument Measurement Geometry

Continuous, fixed-beam vertical scanning or continuous conical scanning (see Section 1.5).

4.1.7 Manufacturer of Sensor/Instrument

NOAA/ETL
325 Broadway
Boulder, CO 80303

4.2 Calibration

Antenna gain and power pattern have been range-tested. Receiver calibrations are conducted before each field project. Typical measurement accuracies are +/- 1 dB for reflectivity and +/- 5-10 cm/s for radial velocity.

4.2.1 Specifications

None given.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

None given.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

Two scanning modes were used in BOREAS:

- Vertical. The antenna pointed continuously at the zenith for long periods (several hours). In this mode, high-resolution measurements were obtained of the vertical velocity fluctuations in the boundary layer as a function of time and height. It also provided uninterrupted monitoring of cloud conditions over the radar site.
- Conical. The antenna repeated a series of four elevation angle sweeps (35, 51, 69, and 90 degrees above the horizon) every 6 minutes. This mode allowed horizontal components of the wind to be measured in addition to the vertical wind. Postprocessing with VAD software computes profiles of the mean wind, momentum fluxes, and higher order turbulence statistics for a large volume over the radar.

6. Observations

6.1 Data Notes

The vertical data in this part of the cloud radar data set (Part I) are provided only in the form of images. The images are in GIF format, which can be displayed with various graphics packages. The images files are provided for the purpose of giving investigators a visual impression of the cloudiness (layer heights, thicknesses, intensities) and the strength of vertical motion fluctuations in the boundary layer as a function of time and height near the NSA-OJP site.

The radar collects huge amounts of data (100 megabytes per hour, typically), which is why a greatly reduced, processed set of data is provided for distribution by the BOREAS Information System (BORIS). The original data are archived at NOAA/ETL on 46 8-mm digital video tapes in the Common Doppler Radar Data Exchange Format (also called "universal format") that is used by many radar meteorology research groups.

6.2 Field Notes

Extensive field notes were recorded in an electronic log book by the radar crew. These notes contain comments about weather conditions, experimental events, equipment problems, etc. Each entry was automatically tagged with the time in Greenwich Mean Time (GMT), date, and topic category. The notes were recorded in WordPerfect format. The hardcopy printout totals about 100 pages. Notes for specific dates are available, upon request, from Brooks Martner.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The North American Datum of 1983 (NAD83) coordinates of the site are:

```
Lat.  =  55 deg., 56 min., 00 sec., north
Long. =  98 deg., 36 min., 52 sec., west
Alt.  =  290 m MSL
```

This location is the NSA about 60 km west-northwest of Thompson and approximately 1 km northeast of the NSA-OJP flux tower.

7.1.2 Spatial Coverage Map
Not applicable.

7.1.3 Spatial Resolution
Beamwidth = 0.5 degrees
Range resolution = 37.5 m
Range limits = 0.15-12.45 km (= 328 range gates)

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
The radar operated in one of two modes, almost continuously, day and night, during IFC-2 and a few days earlier. The dates of radar operation and some general notes are included in the following table.

Start Date	Start Time (GMT)	End Date	End Time (GMT)	Weather; Scan mode
07/16	22:21	07/17	14:21	mostly clear; vertical
07/17	16:40	07/17	22:10	clear skies; vertical
07/17	22:10	07/18	14:38	clear skies; vertical
07/18	15:50	07/19	00:01	mostly clear; conical
07/19	00:02	07/19	15:08	layer clouds, light rain; conical
07/19	15:14	07/19	21:40	rain; vertical and conical
07/19	21:50	07/20	15:00	rain then overcast; conical
07/20	15:14	07/20	23:15	clearing, cirrus & cumuli; vertical
07/20	23:16	07/21	14:54	cumuli then clear; vertical
07/21	15:15	07/21	22:28	clear; conical
07/21	22:29	07/22	14:33	clouds & showers; vertical
07/22	15:09	07/22	21:33	post-front clear & cloud; conical
07/22	21:33	07/23	15:03	variable cloudiness; conical
07/23	16:02	07/23	22:29	windy, cumuli then clear; vertical
07/23	22:29	07/24	14:33	cloud layers move in; vertical
07/24	14:45	07/24	21:54	stratus; vertical
07/24	21:54	07/25	15:25	cumuli, clear, layers; conical
07/25	15:35	07/25	22:39	showers, deep layer; conical
07/25	22:39	07/26	09:21	clearing; conical
07/26	14:48	07/26	22:47	clear, cloudy, clear; vertical
07/27	15:15	07/27	22:21	cirrus; conical
07/27	22:21	07/28	14:52	cirrus then clear; vertical
07/28	15:01	07/28	22:18	clear; conical
07/28	22:18	07/29	14:11	clear, brief cirrus; vertical
07/29	15:05	07/29	22:16	clear, a few cirrus; conical
07/29	22:16	07/30	14:47	cirrus then clear; vertical
07/30	15:21	07/30	22:20	clear; conical
07/30	22:24	07/31	14:24	clear; vertical

07/31 14:40	07/31 21:15	clear; conical
07/31 21:15	08/01 14:45	clear then cirrus; vertical
08/01 14:56	08/01 22:25	cirrus; conical
08/01 22:25	08/02 14:56	layer clouds, virga; vertical
08/02 15:04	08/02 22:33	cold front clouds; conical
08/02 22:34	08/03 11:03	altostratus, stratus, clear; conical
08/03 15:37	08/03 22:07	cloud layers; vertical
08/03 22:08	08/04 14:08	stratus, clear, cirrus; vertical
08/04 14:19	08/04 22:31	clear; conical
08/04 22:31	08/05 00:54	clear; conical
08/05 15:06	08/05 22:18	cirrus, altostratus; mostly vertical
08/05 22:18	08/06 14:38	increasing clouds, rain; vertical
08/06 15:00	08/06 22:31	stratus; vertical
08/06 22:31	08/07 14:34	thin stratus; vertical
08/07 14:47	08/07 22:01	thin stratus; mostly vertical
08/07 22:01	08/08 10:14	thin stratus, clearing; vertical
08/08 14:38	08/08 18:39	clear, fair weather cumuli; conical
08/08 18:58	08/08 22:57	fair weather cumuli; conical

7.2.2 Temporal Coverage Map

Not available.

7.2.3 Temporal Resolution

Vertical mode:	20 beams/minute for routine averaged data
	(200 beams/minute for raw data)
	30-minute volumes (= 600 beams/volume)
Conical mode:	291 beams/sweep
	1 sweep/90 seconds
	4 sweeps/volume (= 1 volume every 6 minutes)

7.3 Data Characteristics

7.3.1 Parameter/Variable

CLOUD HEIGHT
DOPPLER VERTICAL VELOCITY
RADAR REFLECTIVITY

7.3.2 Variable Description/Definition

CLOUD HEIGHT -- Height of the clouds in km.

DOPPLER VERTICAL VELOCITY -- Warm colors represent upward motion and cool colors signify downward motion. Often, the cloud image covers more area on the velocity image than on the reflectivity image because the radar's velocity measurements can detect weaker targets.

RADAR REFLECTIVITY -- The intensity of the backscattered signal, and for water droplets it is related to the size and concentration of the drops. The hotter the color the stronger the returned signal.

7.3.3 Unit of Measurement

CLOUD HEIGHT	km
DOPPLER VERTICAL VELOCITY	m/sec
RADAR REFLECTIVITY	dbZ

7.3.4 Data Source
Analysis of raw radar data.

7.3.5 Data Range

CLOUD HEIGHT	0-12 km AGL
DOPPLER VERTICAL VELOCITY	-40 to 17.5
RADAR REFLECTIVITY	-40 to 17.5

7.4 Sample Data Record
Not applicable.

8. Data Organization

8.1 Data Granularity
The smallest unit of data tracked by BORIS is the entire set of GIF images.

8.2 Data Format(s)
The entire set of Graphical Interchange Format (GIF) images is stored in a single Unix tar file. Within the file are 603 GIF images. Each image shows a time series profile of the atmosphere as it passed over the radar site.

9. Data Manipulations

9.1 Formulae

9.1.1 Derivation Techniques and Algorithms
The image data contain direct measurements of radar reflectivity and vertical Doppler velocity as recorded by the instrument. The only processing of the measurements is temporal averaging of data. The displayed data have 3-sec resolution, which represents an average of 10 individual raw data beams that are recorded at the rate of one raw beam every 3/10 sec.

9.2 Data Processing Sequence

9.2.1 Processing Steps
See Section 9.1.1.

9.2.2 Processing Changes
None given.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
See Section 9.1.1.

9.3.2 Calculated Variables
See Section 9.1.1.

9.4 Graphs and Plots
The vertical data were provided to BORIS in the form of time-height plots.

10. Errors

10.1 Sources of Error

One known source of error is the strong attenuation of the radar's microwave energy by rainfall. Rain or water on the antenna's waveguide feed window will usually invalidate the reflectivity measurements, although the velocity measurements remain accurate. Very strong targets may also cause saturation of the receiver used for the reflectivity data shown in these images. Range-aliasing (2nd-trip echoes) and velocity aliasing (folding) are not factors for these vertical data.

10.2 Quality Assessment

10.2.1 Data Validation by Source

None given.

10.2.2 Confidence Level/Accuracy Judgment

None given.

10.2.3 Measurement Error for Parameters

For typical conditions, the reflectivity measurements are accurate within +/- 1 dBZ, and the vertical Doppler velocity measurements are accurate to within +/- 5-10 cm/s.

10.2.4 Additional Quality Assessments

None given.

10.2.5 Data Verification by Data Center

BORIS personnel reviewed a random selection of 20 images to be sure that they could be viewed successfully. No problems were encountered during the review.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

None given.

11.3 Usage Guidance

The time-height images are provided to BORIS in order to allow scientists to obtain a general impression of the evolution of cloudiness and boundary layer vertical motions near the NSA-OJP site. The principal investigators should be consulted for a more quantitative use of the vertical data.

11.4 Other Relevant Information

There is one profile of data every 3 seconds, 600 of which are assembled side-by-side in chronological order into these half-hour images. Each image covers 30 minutes of time (the x-axis) and 0-12 km of height above ground (the y-axis). A few specific times are shown at periodic intervals near the top of each image, with the time mark corresponding to the left-hand edge of those time numbers. There is some additional nondata blank space at the end of the y-axis in each image beyond the 30-minute mark, which accounts for the extra pixels. The start time in Universal Time Code (UTC) of each half-hour is shown in the header strip at the top of each image. Thus, the file k01aug94.0815.gif contains the radar data for 08:15-08:45 UTC on 01 August 1994 and shows all radar echoes that passed over the radar during that period between the ground and 12 km height.

12. Application of the Data Set

The data may be useful for extending the height-limited momentum flux measurements.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description

None given.

14.2 Software Access

None given.

15. Data Access

The NOAA/ETL 35-GHz cloud/turbulence radar GIF images are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/ [Internet Link].

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

The complete data set (approximately 48 gigabytes) is archived at NOAA/ETL on 46 8-mm digital video (Exabyte-type) tapes. The data are on tape in the Common Doppler Radar Data Exchange Format used by many radar meteorology research groups.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, Geographic Information System (GIS), and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

The complete data set (approximately 48 gigabytes) is archived at NOAA/ETL on 46 8-mm digital video (Exabyte-type) tapes. The data are on tape in the Common Doppler Radar Data Exchange Format used by many radar meteorology research groups.

17. References

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None given.

19. List of Acronyms

ABL - Atmospheric Boundary Layer
AFM - Airborne Fluxes and Meteorology
AGL - Above Ground Level
ASCII - American Standard Code for Information Interchange
BOREAS - BOReal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
CD-ROM - Compact Disk - Read-Only Memory
DAAC - Distributed Active Archive Center
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
ETL - Environment Technology Laboratory
GIF - Graphical Interchange Format
GIS - Geographic Information System
GMT - Greenwich Mean Time
GSFC - Goddard Space Flight Center
HTML - HyperText Markup Language
IFC - Intensive Field Campaign
NAD83 - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NOAA - National Oceanic and Atmospheric Administration
NSA - Northern Study Area
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
RASS - Radio Acoustic Sounding System
SSA - Southern Study Area
URL - Uniform Resource Locator
UTC - Universal Time Code
VAD - Velocity Azimuth Display

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The BOREAS AFM-6 team from NOAA/ETL operated a 35-GHz cloud-sensing radar in the NSA near the OJP tower from 16-Jul-1994 to 08-Aug-1994. This data set contains a time series of GIF images that show the structure of the lower atmosphere.

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